construction & use of

SIMPLE PHYSICS APPARATUS

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The CONSTRUCTION AND USE OF SIMPLE PHYSICS APPARATUS

by

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The production of this booklet, apart from the cover, has been entirely by the off-set process. The freehand drawings by the author have been retained to maintain the "do it yourself" approach and to keep the price at a level that teachers in developing countries can afford.

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INTRODUCTION

WHY USE SIMPLE APPARATUS?

It is a common mistake to believe that science cannot be taught well without expensive apparatus. Certainly some experiments require complex equipment but in many cases the simpler apparatus enables the pupil to understand the basic principles more easily.

Experiments are frequently used to demonstrate laws that have already been presented to the students in theory lessons. As a consequence, if the class has been led to expect that pressure times volume must be a constant, they will be disappointed to find Boyle's law is not precisely demonstrated in practice.

Educationally it would be preferable to ask the students to investigate the relationship, if any, between pressure and volume. An "inaccurate" result would not then dismay them, and under these circumstances less elaborate apparatus would be quite in order, provided that it were not so inaccurate as would make the law quite improbable.

There are many instances in physics where the exact value of the quantity being measured is of no special significance. In such cases the aim is not, for example, to measure the speed of sound to the nearest centimetre per second, but to understand the problems that arise in carrying out the experiment. Thus methods that draw attention to the errors will provide the teacher with a better opportunity to help pupils identify and solve their difficulties.

Other advantages of simple equipment are as follows:—

1. It is cheaper and therefore makes it possible to provide more apparatus for individual experiments by students.

2. Concern over loss, breakage, and repair is reduced and therefore the equipment is more frequently used.

3. Pupils may became aware that scientific principles apply to everyday things and are not just associated with special apparatus, usually imported from abroad, and only found in laboratories.

4. Pupils realise that no scientific experiment is perfectly accurate, however expensive the apparatus, and attention is drawn to the need to estimate accuracy.

5. Permits pupils to see more clearly where the inaccuracies arise and to appreciate the reasons why the more complex apparatus is designed in the way it is and the need to take great care of it.

6. Encourages pupils to construct simple things for themselves at home and then to explain the scientific ideas to the whole family.

7. It can more easily be taken into the classroom when laboratory facilities are not available.

8. Allows pupils to participate in experimental design and to make suggestions as to how to test a hypothesis. Encouraging pupils to make the most effective use of local resources is especially important in developing countries.

9. A simple experiment, to work effectively, often requires a deep understanding of basic principles and therefore focusses attention on scientific thinking rather than rote memorisation of complex procedures.

The fact that simple experiments are increasingly finding a place in the modern science programmes is a reminder that they should not be thought of as second-class make-shift procedures unlikely to lead to the high standards to which every developing country would wish to aspire. They are not just suitable for rural areas that lack the "proper" equipment, for simple "open-ended" experiments can be devised which will extend even the most gifted urban child.

The use of simple apparatus constructed locally provides a magnificent opportunity for educators in developing countries to extract the essence of a good science education without the expensive frills that have become associated with Western models. It is not just a matter of copying commercially manufactured equipment, which would be difficult in areas where there is a shortage of skilled craftsmen and a lack of workshop facilities, but rather one of adapting items already available on the domestic market. The design details will be largely determined by the items available so the suggestions offered in this booklet should be thought of only as a guide.

When exploring the local bazaar for likely items, particular attention should be paid to toys which, being mass produced, are usually cheap and frequently illustrate the basic principles as well as the standard apparatus imported at a cost grossly out of proportion to the local resources.

The importance accorded to simple equipment is closely associated with our educational objectives. If practical work is considered a waste of time because it contributes little to examination success, then we must modify our examinations accordingly. If our textbooks show traditional equipment & hence discourage alternative ways of illustrating a principle, then we must reword our questions to avoid reference to specific pieces of equipment. If our textbooks put theory before practice and tell the student the right answer then, while teaching, pupils should have their text-books closed and use them only to provide a summary. In marking practical books we must avoid giving undue credit to "correct" results obtained by chance or by "cooking" the results — a thoroughly unscientific occupation.

The choice of equipment is also linked with our teaching methods. Thus if the aim is to teach "the specific gravity bottle" then perhaps you must have one, but if you are considering ways of comparing densities then a "coke" bottle might be quite adequate.

Class questioning techniques also reflect our objectives. If we insist on the right answer then pupils will try to supply it even if it means cheating, but if we welcome wrong answers then we will find out what they fail to understand and hence discover ways to help them. Thus experiments must be considered as a means of stimulating class discussion rather than "cookery book" procedures which must be followed without thinking.

Even though quite a lot of simple equipment is now being distributed commercially there will always be a need for teachers to design and try out experiments themselves. Remember, however that to get simple equipment to "work" often calls for more scientific thinking than the "fool-proof" commercial items, so do not be discouraged too easily.

For more years than I now care to admit, I have found delight in such work and if this little booklet helps others to do likewise then my time will have been well spent. Finally, I would like to acknowledge the inspiration of the late F.A. Meier, the advice of my colleague Terry Allsop, the technical assistance of William Ho, and the stimulation of my students in different parts of the world.

Ray Simpson

May 1972.

HOW TO USE SIMPLE APPARATUS

a) Physics with a Vibrating Strip

Your long-awaited crate of imported scientific apparatus has arrived and you eagerly break it open to see what you have inside, for you have probably forgotten what you ordered so long ago. However, in your haste, do not discard the steel bands that bind the box for they too can be used as scientific apparatus! Indeed, if used properly, a strip of flexible metal may teach the scientific method more effectively than, say, a Wimshurst machine or a Fortin barometer.

Cut the steel strip into lengths of about 2 feet and pass them out to the class with a piece of oil clay (plasticine). Hold one end against the edge of a table and show the class that it can vibrate up and down. Then ask them to find out as much as they can about the way it vibrates. Classes unused to this approach may need plenty of encouragement to get them started, but if pupils ask, "What should we find out, Sir?", you should avoid telling them straight away, and not until they are really stuck should you give them a clue .... "Does the length have an effect?"

The teacher's role is to walk round the laboratory posing questions aimed at leading the class to discover for <u>themselves</u> the various factors involved. After about 15 minutes the class should be asked, group by group, to state what they have discovered. "When it is shorter it goes faster, Sir", might prompt the teacher to vibrate a <u>short</u> strip with <u>small</u> amplitude and ask the class whether they really believe that it is going faster than a <u>longer</u> strip with a <u>larger</u> amplitude ...... Gradually the idea of the <u>period</u> of vibration emerges and perhaps one member of the class has been observant enough to notice that the period seems to be independent of amplitude. However, the teacher should <u>not</u> say, "That is right, very good", but pass the question back to the rest of the class asking them whether they also agree with the observation. If not, ask them to look again.

Some pupils will have put the plasticine on the end of the strip and found out that the period of vibration is increased, and I have no doubt that the more mischievous will have shortened the vibrating length until a twanging noise is produced. This last observation should lead pupils to realise that sound is a form of vibration. (A fact that will not necessarily be appreciated by your colleagues in neighbouring classrooms!) Each conclusion should be recorded by the class and the experiment summarised in diagrammatic form.

b) Playing with Ping Pong Balls

Gravity

Which will hit the ground first when dropped, a light ping-pong ball or a heavy cricket ball? If the pupils are reluctant to reply the teacher might say: "obviously the heavier ball will fall quicker; do you all agree?" It will usually be possible to get most of the class to nod their heads but there are some who have heard otherwise from their elder brothers and will not be taken in. "You are not sure?....." "Why don't we try it and see" ..... Surprise! They both hit the ground at the same time. Possible student conclusion — all bodies fall at the same rate. This should prompt the teacher to hold up a sheet of thin paper with the ping-pong ball ..... the dilemma is apparent ..... "But, Sir, the paper is larger." ..... without saying a word the teacher might screw the paper into a ball .... "Oh, no Sir, when it is flat it has a larger area." ... "Why does that matter?" ..... "Because it has a greater air resistance." "What would happen in a vacuum? ..... What is your guess? ..... well let's try it ..... what apparatus will we need? Would this do? ..... why not? ..... can you suggest a better way?"

Elasticity

Another ping-pong ball experiment involves the idea of elasticity. Arising out of a discussion as to which ball is better, the height of bounce is observed. "How could we do this accurately?" ..... The class is then given a few minutes to think about it ..... they then try out a convenient method ..... "Will the height from which you drop it make a difference?" .....Eventually the class decides that the ratio of new height to original height is the important thing ..... "Will it be constant?" ..... a further investigation.

Discussion of this type should reveal many student misconceptions and result in a number of searching questions from the students. Staff unfamiliar with this method of teaching may wish to pose the questions in such a way that the discussion follows a pre-arranged path. This makes it less likely that the teacher will be asked something he cannot answer but with growing confidence and experience, questions from students should be actively encouraged.

c) Science and Stability

There are a number of simple toys that employ the principle that a body is stable if the centre of gravity is below the point of suspension. Clowns balancing on tight-ropes may be intriguing but it is difficult for the student to test a theory he may have developed to explain it when he does not know where the C.G. of the clown is situated and has no way to vary it so as to see the effect. By using a piece of bent wire attached to a pencil, as in the diagram, it is possible to change the height and weight of the piece of oil clay attached to the end. Apparatus designed in this way makes it more possible for the student to discover the underlying principle for himself — he does not always have to be told the conclusion.

Other common stability topics include the leaning tower of Pisa and the stability of a double-decker bus, but here again the teacher usually tells the class that the vertical through the C.G. must lie within the base, when in fact it is possible for the class to reach this conclusion if the apparatus is redesigned to reveal this.

A block of wood with the approximate shape of a bus can be made and a small nail inserted where the diagonals intersect. The class will be able to tell the teacher that the C.G. lies at this point (but inside the block of course). If a piece of cotton, to which a small nut or washer has been attached as a weight, is attached to the nail so that it hangs over the side of the bench then, as the block is tilted, it is abundently clear that it falls when the vertical reaches the corner of the block. If an extra block is placed on top, corresponding perhaps to additional passengers upstairs, then the consequent change in C.G. and angle of topple is readily seen.

* * * * * * * * * * *

Whenever possible the simple apparatus described in this booklet should be used to encourage student discovery, for unless this method of teaching is adopted an important advantage of simple apparatus will be lost and pupils may come away with the idea that the school is ill-equipped and nothing works properly like it does in the book!

A dollar optical bench

There is really no need for teachers to perform "light" experiments with pins. An ordinary torch bulb taped to a battery provides a source while a lens can be obtained from a toyshop magnifying glass with the plastic handle removed.

The lens can be held in a cork or, if more accurate measurements are required, it can be fixed in a spring "Terry" clip which has been attached to a spring paper clip. A small brass pointer can be soldered in position if necessary.

Rulers 2' or 3' long are usually available in stationery shops, but if not the local tailor will know where to buy one or else use a simple tape measure.

A satisfactory screen can be made from a 2" square piece of stiff translucent plastic which has been roughened with sandpaper.

Light Sources

Even in very under-developed areas it is usually possible to find a torch with battery and bulb. Bulb holders are more difficult and may have to be improvised by twisting ordinary wire round the screw of the bulb itself.

Alternatively if an old set of Christmas tree lights is available then this could provide all the lamp holders needed.

Wires can be fixed to tbe battery terminals using sticky tape and an on/off switch can be made by unscrewing the bulb slightly.

If a 12 volt car battery or mains transformer is available a more powerful source of light can be made easily.

A hole is made in the top of an old tin for the lamp holder and a side panel is cut out with tin snips. A number of small holes may be made in the top for ventilation.

To obtain good results with a spherical lens something approaching a point source of light is desirable, but this is difficult to obtain if a high wattage is required. A better arrangement is to use <u>cylindrical</u> lenses with <u>straight filament</u> light bulbs. The old style car lamps are of this type but may be difficult to locate.

A large aperture mirror

The application of a little metal polish to the inner surface of a biscuit tin produces a reflector suitable for class demonstrations of caustic curves and the tracking of light rays. Plastic coated aluminium foil used for Christmas parcels can also provide a good reflecting surface if stuck to a tin.

Alternatively a strip of tinned sheet about 2" by 12" can be polished and then bent by hand to show how the focus varies with curvature. The effect of a convex surface can also be seen clearly.

An ordinary hair comb provides an excellent way of tracing the individual rays of light.

Some appreciation of spherical aberration can be conveyed with the large aperture mirror and the properties of a parabolic mirror can be introduced with the aid of a reflector from a car or bicycle lamp, by moving a bulb in and out.

Making Plastic Cylindrical Lenses

wooden frame for sieve
fine
coarse
flannel
Plastic Lens
Acrylic Plastic
plano
double

Cylindrical lenses are superior to spherical ones when we want to demonstrate the bending of light rays. Such lenses, having a flat base, can stand up without a holder, and permit the rays to be seen on a piece of paper placed underneath.

It is really very simple to make a cylindrical lens from a piece of acrylic plastic about 2" x 1" x ½" Using a wooden frame for a sieve or a circular shaped tin we can grind the lens by rubbing it on, first coarse, and then fine, emery paper. The final polishing should be done with "brasso" on a soft piece of flannel. The whole process should not take more than an hour and pupils will often be delighted to assist.

The advantage gained by using cylindrical lenses for tracking light rays is not always appreciated. They must be used with straight filament lamps for satisfactory results. The ordinary lamp box with a domestic pearl bulb may provide a bright object but is quite unsuitable for producing good parallel light rays.

It is very convenient to observe images through a ground-glass screen. Ground-glass is very easy to make by placing some carborundum power (used in garages for grinding in the valves) between two plates and then rubbing them together with a circular movement. Sheets of perspex can easily br roughened in this way, but glass is usually cheaper and easier to obtain.

A water prism

Large glass prisms are expensive but a satisfactory alternative can be made with four thin pieces of glass stuck together with a waterproof glue e.g. an epoxy type such as Araldite twin-pack.

The water prism thus formed will not disperse the colours as much as a glass one but it is quite adequate for demonstration purposes.

Plastic "lunch box" refractor

The total internal reflection of a beam of light can easily be shown using a plastic lunch box as the water container.

One with vertical sides should be chosen and white paper should be placed under the box to make the rays show up better. A few drops of fluorescein will also help.

The large size makes it suitable for class demonstrations.

Seeing round corners

Total internal reflection of light can be shown very convincingly with a plastic rod of about half an inch diameter which has been bend as in the picture. If a plastic rod is not available a solid glass rod can serve. The light from a small torch bulb can be seen quite clearly at the other end.

This idea is used in some advertising signs and is also made use of in the new fibre optics employed for taking pictures inside the human body.

Another convenient way of seeing round corners is demonstrated in the periscope.

Periscope

Perhaps the easiest way to make a periscope is to use a P.V.C. or cardboard tube. Cut the ends off at 45 degrees and then make openings by three saw cuts AB, BC and CD. Square mirrors glued on the ends make this a very satisfactory instrument.

Polaroid Possibilities

At the upper secondary level you may be required to teach about polarised light. For this a discarded pair of polaroid sun glasses is convenient. Pieces from the lenses appear black when crossed- a surprising effect indeed. Explanations of this phenomenon are well worth class discussion.

The rotation of the plane of polarisation can be shown by fixing a piece of polaroid to the bottom of a glass bottle or PVC tube and another to the top. If the lid is rotated for maximum transmission with the container empty then the addition of a sugar solution shows that the plane of polarisation has been rotated. It is not suggested that precise quantitative results can be obtained but the idea of a polarimeter is clearly illustrated.

You may have read that polarised light can be produced when light falls on a pile of glass plates at about 57 degrees (Brewster's angle) and is then transmitted. Microscope slides, about six of them, can be wedged in a suitable bottle and the light examined by a piece of polaroid fixed to the rotating lid. You should also examine the sky through a piece of polaroid- it is partially plane-polarised.

A coloured filter can be added for monochromatic light and a pointer and protractor used for more accurate measurements.

Leslie's Cube & Radiation Experiments

Radiation from black and shiny surfaces can be investigated by a Leslie Cube made from a tea tin. The circular hole is just big enough for an electric heater,with wire mesh cover,to be inserted. (This type of heater is used in the Nuffield programme)

The relative warmth of the black and shiny surfaces can be detected by the back of the hand but it is advisable to unplug before doing this just in case the heater element touches the side of the tin.

The traditional experiment in which the cube is filled with hot water requires an expensive thermopile to detect the temperature difference, but with the heater they can be felt by hand.

An even more direct method of detection is to stick a thin piece of aluminium foil on your hand and place it near the opening in an asbestos sheet behind which the heater is placed. A student can keep his hand there almost indefinitely but if the foil is now coated with carbon it is remarkable how quickly he will want to withdraw it.

Yet another alternative is to heat a large metal object,one surface of which is black and another shiny. If it has a large thermal capacity the difference can be felt for a considerable time. Copper is suggested for this in the Nuffield course but it is surprisingly expensive. The choice of a good metal can provoke a useful class discussion.

Davy's Safety Lamp

A wire gauze shield can conduct away heat sufficiently rapidly to prevent a flame burning inside from igniting gases outside. This idea is used in a miner's safety lamp. No doubt such lamps have been replaced by more convenient electric torches but the principle is still of interest to the physics teacher.

To make a model lamp, acquire some gauze of the type that is sometimes used for mosquito netting. An alternative source is a local garage that uses it for petrol filters. The mesh should be quite small.

Cut out the gauze with tin snips and clip it together with ordinary office staples. Place a candle on a dish or tin lid, light it of course, and then cover it with the gauze. Now take a bunsen burner, turn on the gas, and direct it toward the flame. You can clearly see the gas burning inside but it does not light outside.

Demonstrate it and ask your students to draw conclusions - try to avoid telling them the explanation until they have put forward their own ideas.

Black & Shiny Cooking Pots

Black bodies above the temperature of the surroundings lose heat quicker than shiny bodies. To show this experimentally you can buy two identical aluminium cooking pots with lids. Take off the knobs on the lids and insert thermometers.

If one of them is coated with blackboard paint and the other left shiny,and an equal volume of boiling water poured into each,it will enable the differing cooling rates to be studied.

Would it be better to use large or small pots?... We want a large surface area in relation to volume so small pots show the effect better. This might be discussed with the class once the basic idea is clearly established.

By using cooking pots the advantages of cleanliness in the kitchen can be understood as a matter of science as well as health.

Conductivity Experiments

For elementary qualitative work it is quite unnecessary to have a special Ingen-housz rectangular hot water container with rods of different metals projecting. All you need are three different rods-possibly of copper,aluminium and iron. The choice of size enables you to question the class about the possible effects of different lengths and diameters. The need for uniformity should be apparent. Rods about 9" long and 1/8" in diameter are suitable. Workshops with welding facilities may be able to supply such rods.

If the rods are bound together with wire near one end and heated at that point,the varying conductivity can be easily detected by a boy holding the other ends.

The World's Simplest Electric Motor

It is possible to buy a small electic motor very cheaply in nearly every toy shop, but it will be too tiny and too complex for your students to see clearly how it operates. However, an extremely simple one can be made in minutes by winding about a dozen turns of 26 S.W.G. enamelled copper wire over two fingers, or three if yours are small!

Why enamel, you may well ask, but herein lies the secret. In order for a motor to work with a D.C. supply (two torch batteries in this case) it is usual to reverse the direction of current every half turn. However, in this model the current is not reversed, but instead it flows only after each full turn.

This is achieved by rubbing off the enamel with emery paper on one side of the input wire A, and likewise the same side of the output wire B. This means that the battery is only connected for half of the time and the inertia of the coil has to carry it through the other half of the cycle.

A convenient way of supporting the coil is with a couple of paper clips, one end of each being opened up and pushed into a wooden base about 4" by 2" in size. The battery connections can be made to the bottom of the paper clips.

To get it working the coil should be given a spin. The position of the magnet may need to be adjusted for good results. If it still doesn't work then check the paper clips for they seem to be coated with plastic nowadays to prevent them going rusty!

Current Balance

A simple form of current measuring device is employed in the Nuffield course for the teaching of elementary electricity. This uses a drinking straw microbalance with a small magnet ½ inch long and 1/8 inch square in cross-section attached to one end. If the needle pivot is correctly positioned then a small current in a coil of about 15 turns and 1 inch in diameter causes a movement of the magnet within it and a corresponding deflection on the scale.

The current involved is not likely to exceed 1 or 2 A but the copper wire used for the coil should be about 22 SWG so that it remains fairly rigid. The main problem is to get the small magnets but these could be imported by air as they are so small and light.

Motor Effect

Two brass rods (about 1/8" dia.) provide non-magnetic rollers alone which a piece of 22SWG copper wire can move when a current flows through it in a magnetic field. Reversing the battery terminals or the polarity of the magnet alters the direction of movement and enables pupils to discover Fleming's Law for themselves. The copper wire is stretched to make it straight and rigid. It should be light for easy movement and the rods should be cleaned with emery paper to ensure good contact. Do not leave the battery connected - it is virtually a short-circuit!

Making your own magnets

Making magnets can be instructive even though you do not produce anything to compare with the better commercial types which employ special alloys.

A coil of a few hundred turns capable of taking a current of 10 A is needed. If you have a reel of copper wire, wound on a wooden former with a hole in the middle, this would be quite suitable, provided of course that you can locate the two ends of the wire!

For a source of power a 200VA transformer with a 12 volt output is adequate if a 12 volt car battery is not available - don't try torch batteries for they cannot supply the current needed and will soon be finished.

You may have been wondering how you can make a magnet using alternating current. The accompanying diagram should make it clear that provided you do not switch off when the current is zero then all should be well. If not try again.

Another way to obtain a large current is to connect the coil to the mains with a 15 A fuse in circuit. This will blow thereby switching off the supply.

If you do not like the idea of doing this, then an electric heater can be inserted in the circuit as a dropping resistor. This should limit the current to no more than 10 A for a two - bar fire.

Hacksaw blades are useful for magnets because they are brittle and can be broken to show that poles always appear in pairs. A metal file is also effective. If a magnetised file is withdrawn slowly while the current is flowing then it is demagnetised and will no longer pick up filings.

Magnet Magic

"What is keeping the metal pieces in the test-tube apart?"

Of course they are magnets,as the pupils will soon guess,but there is no need to tell them that initially. Even though they know that magnets can repel each other the pupils will still be intrigued to find that with modern magnets one can easily support the weight of another.

Small cylindrical magnets about 3/4" long and 1/2" in diameter can be obtained from small discarded loudspeakers and these are ideal as they just slide into a standard-size test-tube.

When the tube is moved up and down the upper magnet bounces around in a most fascinating manner. Could it be due to a cushion of air? Ask the class how this hypothesis could be put to the test.

Can like poles attract?

If you are lucky to have one of the really big magnets of the type developed for use in a magnetron,then you can really get your senior pupils worried by showing that LIKE poles sometimes appear to attract.

If you bring the N pole of an ordinary bar magnet towards the N pole of a very strong one you will find that, although initially it seems to repel, when you move it nearer still it actually attracts.

Can you explain it? ...Remember the induced magnetism due to the large magnet.

Battery Holders

Many schools are forced to use torch batteries for their electrical supplies. To make easy contact with such batteries a holder is desirable and a number of simple types are illustrated.

In the first the brass cup hooks should be situated a little closer than the battery size so that good contact is obtained. An elastic band between the hooks helps to hold the battery in position.

An alternative is to use spring clips but these are more costly.

If several cells are needed then a good way is to wrap them in a sheet of acetate plastic, the end being stuck down with sticky tape. The battery connections are made with metal rods. (the types used for welding, about 1/10" in diameter, are very suitable) These are pushed through the plastic tube, the hole being elongated to allow some adjustment for good contact, this being maintained by elastic bands. Crocodile clips can be attached to the ends of the rods for the appropriate voltage required.

Commercially made continuously <u>variable resistors</u> are very expensive, but for many school purposes a cheap alternative is available. Resistance wire can be wound round a hardboard former about 2" by 6" in size, the ends being passed through small holes and the whole supported by wooden feet. A crocodile clip provides a simple tapping.

An even simpler scheme, but not so robust, is to employ a pencil lead as a resistor (refills can be bought without the wooden holder). The lead can be fixed down by small pieces of plastic D & E while paper clips A & C wedged under are the fixed contacts and clip B is the slider.

For a <u>fixed</u> resistor a wooden cotton reel provides a convenient former with screws at the top for the connections.

Another form of simple variable resistor can be made with a length of resistance wire using crocodile clips as moving contacts.

If a mains electric supply is available then the <u>teacher</u> may use an electric fire element as a resistor to limit the current.

Generate your own Electricity

In almost any part of the world it is possible to buy a bicycle dynamo and find an old wheel from a baby push-chair. If these are mounted on a wooden board with the lamp connected, then it will glow when the wheel is turned. A handle can be added to get greater speed and more uniform motion.

By replacing the lamp by a milliammeter the changing direction of the current is visible and, as the speed increases, the needle vibrates at the centre zero position. This is helpful in explaining the difference between A.C. and D.C. meters. A radio resistor should be included initially to protect the meter. (100 ohms).

A potato cell

Young pupils are usually surprised that you can produce a source of electricity from a potato or better still a lemon or orange. Just cut one in half and push pieces of zinc and copper into it. A milliammeter will show that a current flows. Zinc can be obtained from the case of an old dry cell and a brass screw can serve as the other terminal. Get the class to try different metals and see what they can discover. It may even be possible to light a torch bulb.

Induced Current Rotating Disc

Have you ever looked inside the electric meter in your home and noticed an aluminium disc rotating between the poles of a magnet. When the power being used increases the disc turns quicker.

To help explain this idea to pupils a light aluminium plate or lid may be balanced on a pointed support. Remember that for stability the C.G. of the plate should be below the point of support - the lip of the plate should ensure this.

If a magnet is rotated by a twisted elastic band just above the plate, the plate will be seen to turn. When the magnet changes its direction of spin so does the plate.

This principle is similar to that used in many car speedometers. In these the magnet is turned by a cable driven indirectly by the wheels. This causes an aluminium disc, on which the speeds have been marked, to turn in proportion to the speed of rotation of the magnet.

Eddy Currents

A ring cut off an aluminum tube, about 1" in diameter, and supported by thread, moves when a magnet is rapidly inserted. The fact that this is due to induced eddy currents can be shown by cutting the ring, thus breaking the circuit. No movement can then be obtained.

Your Electric Iron

Even if you do not wish to repair your own iron you should have some idea of what it looks like inside. An old broken iron should be easily obtainable, or if not, buy a replacement heating element and a thermostat unit.

Mount the mica covered heater on a piece of asbestos and attach briefly to the mains supply. The element glows. (without the metal base do not leave it permanently connected...why?)

Mount the thermostat unit, modified slightly perhaps, so that is is above the heating element just as it would be in the real iron. Complete the thermostat circuit with lamp and battery- the light should be on when cold. To avoid the possible danger of using the electric mains, the heat can be provided by a bunsen burner or a candle directed on to the thermostat. If you have adjusted it correctly then the light should go off and on.

How your fuse works

If you do not wish to risk blowing a mains fuse it is still possible to show the action of a fuse with a low voltage source by employing a single thread of very thin wire from a pad of steel wool as used to clean kitchen pots. If the thread is placed in series with a 2.5 v torch bulb and connections made to one cell it glows dimly; with two it is normal, with three it is over-bright but; with the right choice of thread thickness and a bit of luck, the addition of a fourth battery causes the thread to fuse and break the circuit before the bulb finally blows. If the class is still not convinced you may even have to waste a bulb and show them that 6 volts really would have fused the bulb!

A Simple ticker timer

(perhaps the cheapest + simplest in the world!)

Many dynamics experiments make use of a vibrating "ticker timer" as a means of measuring time intervals.

You can make your own simple version using an electric bell but the design depends on the type of bell available on the local market. The old type with a long clanger is now being replaced by one in which the clanger is inside the bell housing. Using this form it was found desirable to replace the vibrator with a small mini-saw blade about 6" long and ¼" wide held by a strong paper clip. These blades have small projections at the ends which are suitable for striking the carbon paper under which the ticker-tape is running. The tape is guided by staples pushed only partially into the wooden mount. A drawing pin underneath provides a good striking surface.

Some adjustment of the length of the blade is required in order to make it resonate with the A.C. supply frequency. A 6 volt A.C. supply of sufficient power can be obtained from a house bell transformer.and even when this is included the total cost is but a fraction of the commercial models.

(A photograph of the actual timer appears on the front cover)

A number of the new physics programmes use a cart or trolley as a means of investigating the laws of motion. A constant force applied by a stretched elastic band, for example, causes an acceleration which is usually measured by a paper tape passing through a ticker-timer that leaves a series of dots with a varying space between them.

The commercial model weighs about a kilogram and is fitted with ball bearing wheels making them almost frictionless. An alternative form of trolley which is reasonably satisfactory can be made from "Meccano", the well-known children's construction material. Large wheels seem to reduce the friction- can you think why? The weight of the trolley should be increased to about 0.5 Kg.-plasticine can be used for small adjustments. The addition of masses to double or treble the total weight enables the variation of acceleration with mass to be investigated.

A trolley can also be made from a roller skate but care should be taken to ensure that the wheels run very easily. The weight of the skate can be taken as the unit and a second skate fixed on top of the first to double the mass.

A paper clip provides a simple means of fixing the paper tape. Commercially made trolleys usually include an internal spring and a cork for collision experiments and these could be fitted - a piece of clock spring is useful as a spring bumper. The cost of these trolleys is naturally much less than the commercial models.

Hand Stroboscopes

The high speed movement of a vibrating object can apparently be stopped when viewed in light of the same frequency, or a multiple of it. To demonstrate this a circular plywood or hardboard disc about 10" in diameter can be made with slits about ¼ inch wide. A bolt and washers enables the disc to be rotated smoothly with a finger hole. When the speed matches that of the vibrating object, viewed through the slits, it appears to be at rest.

The principle of the stroboscope is used in a record player turntable speed tester. Usually made of aluminium, such discs should be available in most music shops. The markings correspond to 33, 45 & 78 rpm.

Record Player Stroboscope

A small test-tube inserted through the central hole of the disc, enlarged a little if necessary, can be supported on a pencil fixed in a rubber sucker base. Ask the class how the disc can be made to rotate more smoothly. Note that its moment of inertia can be increased with a circular ring of oil clay pressed underneath. Stability is also improved by lowering the centre of gravity.

If the rotating disc is viewed in fluorescent light the 78 rpm markings can be seen to become stationary, followed by the 45 rpm and finally the 33 rpm as the disc slows down.

Water Pressure with Depth – a fallacy

How often have you told your students that the water spurts out further from the lower hole and then asked them to draw the text-book diagram?

Well the textbooks are almost invariably WRONG. They usually show the lowest outlet projecting the furthest at the level of the bottom of the tube.

In fact it can be proved theoretically, and shown experimentally, that the middle outlet projects furthest while the upper and lower ones project an equal but smaller amount.

You may not believe this, so try it yourself using a piece of the new type of PVC water pipe about 3 feet long and 3 inches in diameter. With the smallest drill size available make the three holes, being careful to ensure that they are horizontal and that rough edges are removed so that the water comes out smoothly. If they are not quite vertically under each other then the jets will not interfere as they drop down.

Perhaps you have realised that below the level of the bottom of the tube the position of the jets is as you might expect. Most text-books have cut off the bottom of the jets to save space and thus the error has arisen. The fact that this has been perpetuated by generations of physics teachers is a timely reminder of the need to start from practical observation.

If you are wondering how you will be able to explain this to your class, remember that the time for a drop of water from the lower jet to reach point A is only one third of the time for a drop from the upper jet, as it only has to fall one third of the height.

Weighing Air

To confirm that air has weight it is possible to pump air into a plastic container and reweigh it. The choice of container offers a chance to consider experimental design- a large one holds more air but it weighs more- why is that important? Yes, it is a matter of the percentage change in weight. A strong container enables a greater pressure and hence a greater weight of air but it probably thicker and heavier.

A gallon cooking oil container is excellent for the purpose if it has a tight metal lid into which the valve from an old bicycle inner tube can be fitted. If it cannot be soldered to the lid then rubber washers are sufficient to make it air tight.

To find the mass of the air at normal atmospheric pressure the air can be allowed to escape gradually through a pump connector and collected over water in a transparent container of known volume. Details of this procedure are given in the Nuffield physics course. If the volume and weight of air are known then the density can be calculated.

Experiments with a balloon can also show the increase in weight but do not forget that a deflated balloon displaces very little air and so the "Archimedes" upthrust is changed. This error is avoided if the container is rigid and thus of fixed volume.

If you can find a strong tin with a well-fitting lid then you can produce an explosion that the class will remember for a long time, and you will also be able to teach them some physics.

Put a few c.c.s. of water into the tin before closing the lid tightly and hanging it by strings about 1 ft. long from a retort stand.

MAKE CERTAIN THAT YOUR PUPILS ARE WELL OUT OF THE FIRING LINE and then heat the tin with a bunsen. The water will soon turn to steam and in doing so expand enormously. As a result a great pressure is built up which forces the lid off at high speed.

An observant student should also note that the tin moves in the opposite direction to the lid,but at a much slower speed. One of Newton's Laws of Motion might emerge from class discussion as well as some appreciation of momentum. It should also provide the opportunity to remind students not to throw empty aerosol tins on to a fire.

Another memorable explosion can be produced by a mixture of gas and air in the right (or should it be wrong) proportions. Take a bunsen burner and cover it with a tin in which a hole has been made. Turn on the gas for some while and then light the gas emerging from the top of the tin. Now turn off the bunsen, stand well back and wait and see. As the gas is used up air enters and mixes with it. Eventually the proportion of gas and air becomes an explosive one and a resounding bang is heard. It is not really dangerous but it is better for the teacher not to take a risk, so keep the class out of range or behind a safety screen.

Cartesian Divers

Cartesian divers have been made by generations of teachers and pupils but they do not always work too well and frequently fail to bring out the scientific principles behind their operation.

Pupils can learn a lot by trying to design their own divers. One way is to use 2 or 3 inches of plastic tube of about ¼ inch in diameter,one end of which has been heated and pinched together to close it. A hair clip or an inch or two of wire can be pushed through the lower end of the tube to form the "legs."

If the plastic tube is narrow than a greater movement in the water level can be observed when the pressure is applied. Students should discover this movement themselves and a large change will make it more noticeable.

In order to obtain a large pressure change the neck of the bottle should not be too large and the air space above the water should be reduced. Once again the students should be encouraged to offer their own explanations for class discussion. In this way the diver becomes a scientific investigation and not just an amusing diversion.

Capillary Capers

Two pieces of thin glass about 3 inches square, separated at one edge by a match stick and held together by an elastic band, enable the variation of capillarity with separation to be easily demonstrated. In fact the cost is so small that the class ought to do the experiment in pairs.

If you haven't got a supply of capillary tubing of different diameters it is very easy to make some. All you need is a piece of glass tube about 9" long. When heated in the middle until it melts, it can be stretched leaving quite a long length of capillary tubing. The extent to which you pull it out determines the diameter.

Perhaps you have told your pupils that the level of mercury falls in a capillary tube but have you ever demonstrated this? It is really very simple. All you have to do is to press the capillary tube against the side of the small beaker containing the mercury. The bottom of the tube is still submerged but the opaque mercury no longer blocks our view.

rise in small tube is greater

water

Viscosity in miniature

In upper form work it is quite common to determine the viscosity of glycerine by Stoke's method in which a small sphere is timed during its fall through the liquid.

With balls of a few millimeters in diameter you need several feet of viscous liquid, otherwise the time of fall is so short that it cannot be measured with accuracy. To set up a long tube of liquid is both inconvenient and expensive but fortunately a simple solution is available that gives just as good results.

A very small sphere is easily obtained from the end of an old ball-point pen. Such a sphere, which is less than a millimeter in diameter, falls so slowly that it can be timed over as little as three inches of glycerine.

To facilitate the timing a piece of graph paper can be wrapped round the large boiling tube which provides a suitable container. With the centre section cut out the passage of the ball can be clearly judged. When the ball reaches the bottom it can be easily retrieved with a magnet and slowly moved back to the top again.

A further advantage of a small ball is that the "wall effect" is minimised.

Come fly with me

If you ask your class, "Why does an aeroplane fly?", they will probably say, "because of the jets or propellers." If you ask, "What makes it go up?", they will often say, "the wind presses underneath the wing as it goes along."

With young pupils it may be as well to leave it at that, but with older ones you may wish to introduce Bernoulli's principle.

All ages should enjoy doing these little experiments:-

1. Below across the top of a thin piece of paper and watch it rise up (not down as might be expected)

2. Do the same with an aerofoil-shaped paper supported on a pencil.

3. Blow under an arch of paper and note the middle go down, again contrary to expectations.

4. Place a lighted candle behind a small card. When you blow, the candle flame is sucked back.

5. Blow air across the top of a small tube dipping in a liquid and see it rise up — this is the principle of a scent spray.

6. Perhaps most impressive of all is to blow down a funnel and find that a ping pong ball is actually held up.

After such experiences pupils should be able to explain the action of a helicopter.

<u>A Short List of Books on Experimental and Laboratory Techniques in the Teaching of Physics</u>

Beleson and Creaser, Techniques and Apparatus for the Science Teacher, O.U.P. (Cheap and intended for developing countries)

Belham, Projects in Physics, Batsford. (for the school science club)

Hoischen, Physics Experiments, Burke, London. (Experiments not normally found in school textbooks)

Hopwood, Science Model Making, John Murray. (Valuable if the school has a small workshop)

Improving Science Teaching Equipment Worldwide, Science Teaching Center, University of Maryland, U.S.A. (A comprehensive guidebook with construction details)

Jardine, Physics is Fun, Books 1-4, Heinemann. (A modern textbook with many simple experiments)

Laybourn and Bailey, Practical Science for Secondary Schools, Books 1-4, U.L.P. (A textbook using simple experiments from which the theory is developed)

Matthews, Instructions in Scientific Hobbies, Museum Press.

McKay, Toys and Inventions, O.U.P. (and several others in this series by the same author — many interesting everyday scientific phenomena are discussed.

Nuffield Junior Science, "Apparatus", Collins.

Nuffield Physics, Experiment and Teachers' Guides I-V, Longmans/Penguin. (Worth consulting for modern methods)

Schools Council, Science 5-13, Science with Toys, Macdonald.

School Science Review, Association for Science Education, U.K. (This 4 per annum publication contains many suggestions — the school should get this regularly)

Science Masters Book — Physics (Series I, Part I, Series II, Part I, Series III, Part I, Series IV, Part I), John Murray.

Unesco Sourcebook, Science Experiments with Simple Equipment (the Asian Edition published by Tuttle is cheaper)

Vries, The Book of Experiments (also the second and third books), John Murray. (Things that could be tried out at home)

magnet
needle
coil
straw
scale
lamp
thermostat
paper clips
coil
iron
element
N
A
B
S
slits
handle
finger
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